TITLE OF THE INVENTION

IMAGE PROCESSING APPARATUS AND IMAGE PROCESSING METHOD

FIELD OF THE INVENTION

The present invention relates to an image processing apparatus and an image processing method, and more particularly, to an image processing apparatus and an image processing method for pseudo-halftoning by performing error diffusion processing on multivalued image density data.

BACKGROUND OF THE INVENTION

Conventionally, the error diffusion method is known as pseudo-halftoning to represent a multivalued image in binary representation (See "An Adaptive Algorithm for Spatial Gray Scale" in Society for Information Display 1975 Symposium Digest of Technical Papers, 1975, pp. 36). According to this method, assuming that a pixel of interest is P and its density is v, densities of adjacent pixels P0 to P3 of the pixel of interest P, v0 to v3, and a threshold value for binarization is T, a binarization error E in the pixel of interest P is distributed by empirically obtained weighting coefficients W0 to W3 into the adjacent pixels P0 to P3 so that a mean density is macroscopically equal to an original image density.

For example, when the value of output binary data is "o",

If $v \geq T$ holds, $o=1$, $E=v-Vmax$; ...(1)

If $v<T$ holds, $o=0$, $E=v-Vmin$;

(Vmax: maximum density, Vmin: minimum density)

$v0=v0+E\times W0$; ...(2)

$v1=v1+E\times W1$; ...(3)

$v2=v2+E\times W2$; ...(4)

$v3=v3+E\times W3$; ...(5)

(Example of weighting coefficients: $W0=7/16$, $W1=1/16$, $W2=5/16$, $W3=3/16$)

Conventionally, when a multivalued image is outputted by a color ink-jet printer or the like using 4 color inks of cyan (C), magenta (M), yellow (Y) and black (K), the pseudo-halftoning is performed by using the error diffusion method or the like for each color. Regarding each color, the processing provides an excellent visual characteristic, however, regarding overlapped two or more colors, does not always provide such a excellent visual characteristic.

To solve this problem, Japanese Published Unexamined Patent Application Nos. Hei 8-279920 and Hei 11-10918 disclose halftoning to obtain an excellent visual characteristic even in overlapped two or more colors by using the error diffusion method for combination of two or more colors.

Further, Japanese Published Unexamined Patent

Application No. Hei 9-139841 discloses similar improvement by performing pseudo-halftoning independently on two or more colors and then correcting output values by the sum of input values.

Especially, to reduce graininess of intermediate density area of color image, it is effective to perform image formation avoiding overlap between cyan (C) component and magenta (M) component, and for this purpose, the following method is employed.

Fig. 24 shows image formation control according to a conventional ink-jet method.

In this figure, image data is multivalue data where each density component (YMCK) of each pixel is represented as 8-bit data (0-255 gray-scale value).

Assuming that densities of C and M components of original image are C and M, densities Ct and Mt of the C and M components of pixel of interest in the multivalue color image are represented as follows.

Ct=C+Cerr

Mt=M+Merr

Cerr and Merr are error-diffused values of the C and M components with respect to the pixel of interest.

As shown in Fig. 24, regarding C and M image formation, 4 types of image formation controls are performed in accordance with the densities of the C and M components of the pixel of interest.

1. If the sum of (Ct+Mt) is equal to or less than a

threshold value (Threshold1), i.e., the value belongs to an area (1) in Fig. 24, dot printing is not performed using C or M inks.

2. If the sum of (Ct+Mt) is greater than the threshold value (Threshold1) and the sum of (Ct+Mt) is less than another threshold value (Threshold2), and Ct>Mt holds, i.e., the value belongs to an area (2) in Fig. 24, dot printing using only the C ink is performed.

3. If the sum of (Ct+Mt) is greater than the threshold value (Threshold1) and the sum of (Ct+Mt) is less than the other threshold value (Threshold2), and Ct≤Mt holds, i.e., the value belongs to an area (3) in Fig. 24, dot printing is performed using only the M ink.

4. If the sum of (Ct+Mt) is equal to or greater than the other threshold value (Threshold2), i.e., the value belongs to an area (4) in Fig. 24, dot printing is performed using the C and M inks.

Note that Threshold1<Threshold2 holds.

However, in the above conventional art, as the image formation for the C and M components differs in accordance with the sum of the density values of the C and M components, the image formation control must be simple. If pixels where image data to be processed changes prior near a threshold value are adjacent to each other, a pixel where the C ink and the M ink overlap with each other and a pixel where these inks do not overlap with each other mixedly appear in the narrow

area, and as a result, the quality of image formation is degraded.

To prevent the degradation of image quality, more complicated thresholds may be employed. However, the threshold condition processing must be more complicated, and processing time is prolonged.

Further, since the conventional threshold processing must be inevitably simple in the processing based on the sum of the density values of the C and M components, flexible processing cannot be performed without difficulty.

Further, if exclusive error diffusion is to be performed by using the sum of three components including the black (K) component, the processing becomes very complicated as represented in the following code.

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Ct=C+Cerr
Mt=M+Merr
Kt=K+Kerr
If(Ct+Mt+Kt>Threshold1)
If(Ct+Mt+Kt<Threshold2)
If(Ct>Mt&&Ct>Kt)
 Print C
Else
If(Mt>Ct&&Mt>Kt)
 Print M
Else
 Print K
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Else
      If(Ct+Mt+Kt<Threshold 3)
If(Ct<Mt&&Ct>Kt)
 Print M
 Print K
Else
If(Mt<Ct&&Mt<Kt)
 Print C
 Print K
Else
 Print C
 Print M
Else
 Print C
 Print M
 Print K
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Further, in the above conventional art, the input multivalued image data is merely binarized by each color component and subjected to the error diffusion processing as the pseudo-halftoning. On the other hand, in accordance with the progress of color image printing technology by the ink-jet method, some ink-jet printers can handle multivalued image data for color image printing by drop modulation or use of same-color thick and thin inks.

Accordingly, it is desirable to apply multivalue

error diffusion processing to the above ink-jet printer. However, in the multivalue error diffusion processing, as the threshold condition processing is so complicated, if the processing is applied to an actual printer, the reduction of printing speed is conceivable. For this reason, upon application of the multivalue error diffusion processing to an ink-jet printer to handle multivalued image data, a processing method capable of maintaining a high processing speed is desirable.

Further, as in the case of the above conventional art, in image formation by completely and exclusively arranging C component and M component dots, in an original image having respectively 50% C and M component, all the pixels are filled with C ink dots or M ink dots, ideally, as shown in Fig. 25A. In this state, if C-ink dot positions and M-ink dot positions are relatively shifted from each other for some reason as shown in Fig. 25B, the image has pixels where C-ink dot and M-ink dot overlap with each other (bluish pixels) and blank pixels without dot throughout most of the image.

Accordingly, in printing by an ink-jet printer using a printhead where C-ink nozzles and M-ink nozzles are arrayed in a scan direction of a carriage of the printer, a formed image periodically changes in accordance with the position of the carriage in the scan direction by variation in carriage scan speed or the like, as shown in Figs. 25A and 25B, and it looks to a

human eye that the density of corresponding area periodically changes due to the variation in probability of occurrence of blank pixels. In other words, to a human eye, the printed result appears as a low-quality image.

On the other hand, if C-ink dots and M-ink dots are independently arranged in an image formation, in an original image having respectively 50% C and M components as in the above case, blank pixels, pixels printed only with the C ink, pixels printed only with the M ink, and pixels printed with both the C and M inks are formed respectively at 25% occurrence uniformly in the formed image, ideally, as shown in Fig 26A.

In the independent arrangement of C-ink dots and M-ink dots, a pixel to be printed only with the C ink may overlap with an adjacent pixel to be printed with the M ink, as shown in Fig. 26B, on the other hand, there is a probability that a pixel to be printed with both the C and M inks is printed with only the C ink or the M ink. Thus, the overall density change is small in comparison with the exclusive arrangement of C-ink and M-ink dots.

Accordingly, it is understood that the exclusive arrangement of C-ink and M-ink dots has a problem that the uniformity of image is degraded from intermediate to high density areas in view of a trade-off between the effect of reduction of graininess in a highlight portion

and image formation accuracy. If only the highlight portion is taken into consideration, as respective dots are initially arranged sufficiently away from each other, the degradation of image quality due to shift of dot positions is very little and the advantage of the exclusive arrangement is rather greater.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an image processing apparatus and an image processing method capable of (1) forming a high quality image by performing high-speed error diffusion processing by performing more complicated threshold condition processing in a simple manner; (2) forming a high quality image at a high speed while using multivalue error diffusion processing; and (3) forming a high quality image by performing optimum pixel arrangement in accordance with image density.

According to one aspect of the present invention, the foregoing object is attained by providing an image processing apparatus for performing error diffusion processing on multivalued image data having plural density components and outputting the result of the error diffusion processing, comprising: first determination means for, upon execution of the error diffusion processing on a first density component among

the plural density components, determining a threshold value used in the error diffusion processing based on a density value of a second density component; first error diffusion execution means for executing the error diffusion processing on the first density component based on the threshold value determined by the first determination means; first output means for outputting the result of execution of the error diffusion processing by the first error diffusion execution means; second determination means for, upon execution of the error diffusion processing on the second density component among the plural density components, determining a threshold value used in the error diffusion processing based on a density value of the first density component; second error diffusion execution means for performing the error diffusion processing on the second density component based on the threshold value determined by the second determination means; and second output means for outputting the result of execution of the error diffusion processing by the second error diffusion execution means.

It is preferable that the first and second determination means use a table showing a relation between density and threshold values, for determining the threshold values.

It may be arranged such that the first and second determination means respectively determine plural

threshold values for N-ary conversion as well as binarization. In this case, it is preferable that the first and second determination means respectively use plural tables for determining the plural threshold values.

Further, it may be arranged such that the apparatus further comprises: third determination means for, upon execution of the error diffusion processing on a third density component among the plural density components, determining a threshold value used in the error diffusion processing based on the sum of the density values of the first and second density components; third error diffusion execution means for executing the error diffusion processing on the third density component based on the threshold value determined by the third determination means; and third output means for outputting the result of execution of the error diffusion processing by the third error diffusion execution means.

In this manner, it is preferable that in a case where the error diffusion processing is performed on the first to third density components, the first determination means determines the threshold value used in the error diffusion processing on the first density component, based on the sum of the density value of the second density component and a density value of the third density component, and the second determination

means determines the threshold value used in the error diffusion processing on the second density component, based on the sum of the density value of the first density component and the density value of the third density component.

Note that the plural density components are a yellow component, a magenta component, a cyan component and a black component, and the first density component is the cyan component, the second density component is the magenta component, and the third density component is the black component.

Further, it is preferable that the apparatus further comprises image formation means such as an ink-jet printer for inputting the error diffusion processing results outputted from the first, second and third output means and performing image formation.

It is preferable that the ink-jet printer has an ink-jet printhead that discharges ink by utilizing thermal energy, and the ink-jet printhead has electrothermal transducers for generating the thermal energy to be supplied to the ink.

According to another aspect of the present invention, the foregoing object is attained by providing an image processing method for performing error diffusion processing on multivalued image data having plural density components and outputting the result of the error diffusion processing, comprising: a first

determination step of, upon execution of the error diffusion processing on a first density component among the plural density components, determining a threshold value used in the error diffusion processing based on a density value of a second density component; a first error diffusion execution step of executing the error diffusion processing on the first density component based on the threshold value determined at the first determination step; a first output step of outputting the result of execution of the error diffusion processing at the first error diffusion execution step; a second determination step of, upon execution of the error diffusion processing on the second density component among the plural density components, determining a threshold value used in the error diffusion processing based on a density value of the first density component; a second error diffusion execution step of performing the error diffusion processing on the second density component based on the threshold value determined at the second determination step; and a second output step of outputting the result of execution of the error diffusion processing at the second error diffusion execution step.

According to still another aspect of the present invention, the foregoing object is attained by providing a computer readable storage medium for storing a program for executing the above image processing method.

In accordance with the present invention as described above, when error diffusion processing is performed on multivalued image data having plural density components and the result of processing is outputted, upon execution of the error diffusion processing on the first density component among the plural density components, a threshold value to be used in the error diffusion processing is determined based on the density value of the second density component, then the error diffusion processing is executed on the first density component based on the determined threshold value, and the result of execution of the processing is outputted. Further, upon execution of the error diffusion processing on the second density component among the plural density components, a threshold value to be used in the error diffusion processing is determined based on the density value of the first density component, then the error diffusion processing is executed on the second density component based on the determined threshold value, and the result of execution of the processing is outputted.

According to still another aspect of the present invention, the foregoing object is attained by providing an image processing apparatus for performing error diffusion processing on multivalued image data having plural density components and outputting the result of the error diffusion processing, comprising: calculation

means for calculating the sum and difference between density values of the first density component and second density component among the plural density components; M-ary conversion means for converting the sum value into M-ary code by using a first function based on the sum; N-value conversion means for converting the difference value into N-ary code by using a second function based on the difference; and execution means for executing multivalue error diffusion processing respectively on the first and second density components, based on the result of conversion by the M-ary conversion means and the result of conversion by the N-ary conversion means.

Note that M and N are respectively a positive integer equal to or greater than 3.

Further, it is preferable that the first function used in the M-ary conversion means is represented in a first table showing a relation between the sum value and an M-ary code, and the second function used in the N-ary conversion means is represented in a second table showing a relation between the difference value and an N-ary code.

Further, it is preferable that the multivalue error diffusion processing is executed by the execution means by using a two-dimensional table with the result of the conversion by the M-ary conversion means and the result of the conversion by the N-ary conversion means as functions. It may be arranged such that the two-

dimensional table is a common table for the first and second density components, otherwise, the two-dimensional table is prepared respectively for the first and second density components.

In the above case, the plural density components are a yellow component, a magenta component, a cyan component and a black component, and the first density component is the cyan component, and the second density component is the magenta component.

Further, it is preferable that the apparatus further comprises image formation means such as an ink-jet printer for inputting the error diffusion processing results and performing image formation.

It is preferable that the ink-jet printer has an ink-jet printhead that discharges ink by utilizing thermal energy, and the ink-jet printhead has electrothermal transducers for generating the thermal energy to be supplied to the ink.

According to still another aspect of the present invention, the foregoing object is attained by providing an image processing method for performing error diffusion processing on multivalued image data having plural density components and outputting the result of the error diffusion processing, comprising: a calculation step of calculating the sum and difference between density values of first density component and second density component among the plural density

components; an M-ary conversion step of converting the sum value into M-ary code by using a first function based on the sum; an N-ary conversion step of converting the difference value into N-ary code by using a second function based on the difference; and an execution step of executing multivalue error diffusion processing respectively on the first and second density components, based on the result of conversion at the M-ary conversion step and the result of conversion at the N-ary conversion step.

According to still another aspect of the present invention, the foregoing object is attained by providing a computer readable storage medium for storing a program for executing the above image processing method.

In accordance with the present invention as described above, when error diffusion processing is performed on multivalued image data having plural density components and the result of the error diffusion processing is outputted, the sum and the difference between the density value of the first density component and that of the second density component among the plural density components are calculated, the sum value is converted into M-ary code by using the first function based on the sum, while the difference value is converted into N-ary code by using the second function based on the difference. Then multivalue error diffusion processing is performed on the first density component

and the second density component based on the results of the M-ary conversion and the N-ary conversion.

According to still another aspect of the present invention, the foregoing object is attained by providing an image processing apparatus for performing error diffusion processing on multivalued image data having plural density components and outputting the result of the error diffusion processing, comprising: analysis means for examining density values of a first density component and a second density component among the plural density components; and control means for exclusively or independently outputting the result of the error diffusion processing on the first density component and that of the error diffusion processing on the second density component, in accordance with the result of analysis by the analysis means, wherein if at least one of the first and second density components has an intermediate density value, the control means independently outputs the results of the error diffusion processing, while if the first and second density components do not have an intermediate density value, exclusively outputs the results of the error diffusion processing.

It may be arranged such that the analysis means includes: first comparison means for comparing the sum of the density values of the first and second density components among the plural density components with a

predetermined threshold value; and second comparison means for comparing the density value of the first density component and the density value of the second density component with each other, and that the control means performs printing by the error diffusion processing based on the first density component or the second density component, based on the results of comparison by the first and second comparison means.

Further, it is preferable that the apparatus further comprises third comparison means for comparing the density value of the first density component with the predetermined threshold value, and the control means further determines whether or not printing by the error diffusion processing is to be performed not only based on the first density component, but also based on the result of comparison by the third comparison means.

Otherwise, it is preferable that the apparatus further comprises fourth comparison means for comparing the density value of the second density component with the predetermined threshold value, and the control means further determines whether or not printing by the error diffusion processing is to be performed not only based on the second density component, but also based on the result of comparison by the fourth comparison means.

In the above case, the plural density components are a yellow component, a magenta component, a cyan component and a black component, and the first density

component is the cyan component, and the second density component is the magenta component.

It may be arranged such that the plural density components of the multivalued image data are respectively binarized by the error diffusion processing, otherwise, the plural density components of the multivalued image data are respectively converted into N-ary code ($N \geq 3$ positive integer) by the error diffusion processing. Further, it may be arranged such that the apparatus further comprises a table showing relation between a density value and an N-ary code output value, for the N-ary conversion. It may be arranged such that the table is a common table for the first and second density components, otherwise, the table is prepared respectively for the first and second density components.

Further, it is preferable that the apparatus further comprises image formation means such as an ink-jet printer for inputting the result of execution of the error diffusion processing and performing image formation.

It is preferable that the ink-jet printer has an ink-jet printhead that discharges ink by utilizing thermal energy, and the ink-jet printhead has electrothermal transducers for generating the thermal energy to be supplied to the ink.

Note that the intermediate density is higher than an approximately half level of a maximum density level.

According to still another aspect of the present invention, the foregoing object is attained by providing an image processing method for performing error diffusion processing on multivalued image data having plural density components and outputting the result of the error diffusion processing, comprising: an analysis step of examining density values of a first density component and a second density component among the plural density components; and a control step of exclusively or independently outputting the result of the error diffusion processing on the first density component and that of the error diffusion processing on the second density component, in accordance with the result of analysis at the analysis step, wherein at the control step, if at least one of the first and second density components has an intermediate density value, the results of the error diffusion processing are independently outputted, while if the first and second density components do not have an intermediate density value, the results of the error diffusion processing are exclusively outputted.

According to still another aspect of the present invention, the foregoing object is attained by providing a computer-readable storage medium holding a program for execution of the above-described image processing method.

In accordance with the present invention as described above, when error diffusion processing is

performed on multivalued image data having plural density components and the result of processing is outputted, the density value of the first density component and that of the second density component among the plural density components are examined, and in accordance with the result of analysis, the results of error diffusion processing on the first and second density components are exclusively outputted unless the density components of the first and second density component have intermediate densities, otherwise, independently outputted if at least one of the first and second density components has an intermediate density.

The invention is particularly advantageous since the error diffusion processing is performed in consideration of the value of another density component, image formation in consideration of overlap with another component is possible, and a high quality image can be formed.

Further, as the threshold used in the error diffusion processing is determined by using a table, the error diffusion processing can be performed at a high speed by performing more complicated threshold condition processing in a simple manner.

Further, when error diffusion processing is performed on multivalued image data having plural density components and the result of processing is outputted, the sum and difference between the density

value of the first density component and that of the second density component among the plural density components are calculated, and the sum value is converted into M-ary code by using the first function based on the sum, while the difference value is converted into N-ary code by using the second function based on the difference. Then based on the results of M-ary and N-ary conversion, the multivalue error diffusion processing is performed on the first and second density components. Accordingly, complicated threshold condition processing accompanying the multivalue error diffusion processing becomes unnecessary due to representing the first and second functions in the form of table, introducing the tables into the multivalue error diffusion processing, and performing the error diffusion processing by referring to these tables. Thus the multivalue error diffusion processing can be performed at a high speed.

Further, when error diffusion processing is performed on multivalued image data having plural density components and the result of processing is outputted, the density value of the first density component and that of the second density component among the plural density components are examined, and in accordance with the result of analysis, the results of error diffusion processing on the first and second density components are exclusively outputted unless the

density components of the first or second density component have intermediate densities, otherwise, independently outputted if at least one of the first and second density components has an intermediate density. Accordingly, the graininess from highlight to intermediate density areas in the image can be reduced, and the uniformity of the image can be maintained from the intermediate to high density areas, thus a high quality image can be formed.

Other features and advantages of the present invention will be apparent from the following description taken in conjunction with the accompanying drawings, in which like reference characters designate the same name or similar parts throughout the figures thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

Fig. 1 is a block diagram showing a schematic configuration of an information processing system according to a common embodiment of the present invention;

Fig. 2 is a block diagram showing a hardware construction of host device 51 and that of image output device 52 constructing the information processing system;

Fig. 3 is a perspective view of an ink-jet printer IJRA as a typical embodiment of the image output device 52;

Fig. 4 is a block diagram showing a software construction used in the information processing system;

Fig. 5 is a flowchart showing the outline of image processing;

Fig. 6 is a flowchart showing image formation control according to a first embodiment of the present invention;

Figs. 7A to 7C are diagrams showing threshold conditions used in the first embodiment;

Figs. 8A to 8C are diagrams showing other threshold conditions used in the first embodiment;

Figs. 9A to 9D are diagrams showing examples of applicable various threshold conditions;

Fig. 10 is a flowchart showing the image formation control according to a second embodiment of the present invention;

Figs. 11A to 11C are diagrams showing threshold conditions used in the second embodiment;

Figs. 12A to 12C are diagrams other threshold conditions used in the second embodiment;

Fig. 13 is a flowchart showing the image formation control according to a third embodiment of the present invention;

Fig. 14 is a flowchart showing the image formation control according to a fourth embodiment of the present invention;

Fig. 15 is a diagram showing threshold conditions used in the fourth embodiment;

Fig. 16 is a flowchart showing the image formation control according to a fifth embodiment of the present invention;

Fig. 17 is a diagram showing threshold conditions used in the fifth embodiment;

Fig. 18 is a diagram showing a two-dimensional common table for C and M components used in the fifth embodiment;

Figs. 19A to 19B are diagrams showing two-dimensional tables specialized for the C and M components;

Fig. 20 is a flowchart showing the image formation control according to a sixth embodiment of the present invention;

Fig. 21 is a diagram showing threshold conditions used in the sixth embodiment;

Fig. 22 is a flowchart showing the image formation control according to a seventh embodiment of the present invention;

Fig. 23 is a diagram showing threshold conditions used in the seventh embodiment;

Fig. 24 is a diagram showing the image formation control according to the conventional ink-jet method;

Figs. 25A and 25B are diagrams showing image formation by exclusively arranging the C and M components; and

Figs. 26A to 26B are diagrams showing image formation by independently arranging the C and M components.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will now be described in detail in accordance with the accompanying drawings.

[Common Embodiment]

First, the outline of a common information processing system used in the following embodiments, the outline of hardware construction, the outline of software construction and the outline of image processing will be described.

Fig. 1 is a block diagram showing a schematic configuration of the information processing system according to a common embodiment of the present invention.

As shown in Fig. 1, the information processing system has a host device 51 comprising a personal computer or the like, and an image output device 52 comprising a printer or the like, interconnected via a bidirectional interface 53. Driver software 54, to which the present invention is applied, is loaded into a memory of the host device 51.

1. Hardware Construction of Host Device 51 and Image Output Device 52

Next, the hardware construction of the host device 51 and that of the image output device 52 will be described.

Fig. 2 is a block diagram showing the hardware construction of the host device 51 and that of the image output device 52 constructing the information processing system.

As shown in Fig. 2, the host device 51, having a processor 1000 and its peripheral devices, serves as a host device. Further, the image output device 52 has a driving portion including a printhead 3010, a carrier (CR) motor 3011 to drive a carrier to move the printhead 3010, a linefeed motor 3012 to feed paper and the like, and a control circuit 3013.

The processor 1000 of the host device 51 includes an MPU 1001 which controls the overall operation of the host device in accordance with a control program, a bus

1002 which interconnects system constituent elements, a DRAM 1003 for temporarily storing programs executed by the MPU 1001 and data, a bridge 1004 which connects the system bus, the memory bus and the MPU 1001, and a graphic adapter 1005 having a control function to display graphic information on a display device 2001 such as a CRT.

Further, the processor 1000 has an HDD controller 1006 which serves as an interface between the processor and an HDD device 2002, a keyboard controller 1007 which serves as an interface between the processor and a keyboard 2003, and a communication I/F 1008 as a parallel interface for communication between the processor and the image output device 52 according to the IEEE 1284 standards.

Further, the processor 1000 is connected, via the graphic adapter 1005, to the display device 2001 (CRT in this embodiment) which displays graphic information and the like for an operator. Further, the processor 1000 is connected, via respective controllers, to the hard disk drive (HDD) device 2002 as a large capacity storage device holding programs and data and the keyboard 2003.

On the other hand, the control circuit 3013 of the image output device 52 has an MCU 3001, having a control program execution function and a peripheral device control function, which controls the overall operation of the image output device main body 52, a system bus

3002 which interconnects the respective constituent elements of the control circuit, and a gate array (G.A.) 3003 including mechanisms to supply print data to the printhead 3010, to perform memory address decoding, and to generate a control pulse to the carrier motor and the like, as a control circuit.

Further, the control circuit 3013 has a ROM 3004 for storing the control programs executed by the MCU 3001, host print information and the like, a DRAM 3005 for storing various data (image print information, print data to be supplied to the printhead and the like), a communication I/F 3006 as a parallel interface for communication between the control circuit and the host device 51 according to the IEEE 1284 standards, and a head driver 3007 which converts a head print signal outputted from the gate array 3003 into an electric signal to drive the printhead 3010.

Further, the control circuit 3013 has a CR motor driver 3008 which converts the carrier motor control pulse outputted from the gate array 3003 into an electric signal to actually drive the carrier (CR) motor 3011, and an LF motor driver 3009 which converts a linefeed motor control pulse outputted from the MCU 3001 into an electric signal to actually drive the linefeed motor.

Next, a particular structure of the image output device 52 will be described.

Fig. 3 is a perspective view of an ink-jet printer IJRA as a typical embodiment of the image output device 52.

In Fig. 3, a carriage HC is engaged with a spiral groove 5004 of a lead screw 5005 which rotates via drive force transmission gears 5009 to 5011 interlocking with forward/reverse rotation of a driving motor 5013. The carriage HC has a pin (not shown) and it reciprocates in directions indicated by arrows a and b, held by a guide rail 5003. The carriage HC has an ink-jet cartridge IJC which integrally comprises a printhead IJH and an ink tank IT. A paper holding plate 5002 presses a print sheet P against a platen 5000 along the moving direction of the carriage HC. Photocouplers 5007 and 5008 are home position detecting members for checking the existence of lever 5006 of the carriage in this area and changing over the rotational direction of the motor 5013. A support member 5016 supports a cap member 5022 for capping the front surface of the printhead IJH. A suction member 5015 performs suction-recovery of the printhead by sucking the inside of the cap member 5022 via a cap inner opening 5023. Member 5019 allows a cleaning blade 5017 to move in back-and-forth directions. A main body support plate 5018 supports the member 5019 and the cleaning blade 5017. It is apparent that any well-known cleaning blade is applicable to the printer of the embodiment. Numeral 5021 denotes a lever for

starting the sucking operation of the suction-recovery. The lever 5021 moves along the movement of a cam 5020 engaged with the carriage HC. A well-known transmission mechanism such as clutch change over controls a drive force from the driving motor.

When the carriage HC is at the home position area, a desired one of these capping, cleaning and suction-recovery is executed at its corresponding position by the lead screw 5005. The timing of any of these processings is not limited to the printer of the embodiment, if a desired processing is performed at a well-known timing.

Note that as described above, the ink tank IT and the printhead IJH may be integrally formed as an exchangeable ink cartridge IJC. Further, it may be arranged such that the ink tank IT and the printhead IJH can be separated, and when ink is exhausted, only the ink tank IT is exchanged for new one.

Further, the control circuit described above with reference to Fig. 2 is included in the ink-jet printer IJRA.

The printhead IJH prints a color image by using at least four color inks of yellow (Y), magenta (M), cyan (C) and black (K) based on multivalued density data of respective YMCK components.

2. Outline of Software Construction and Outline of Image Processing

Fig. 4 is a block diagram showing the software construction used in the above-described information processing system.

As it is understood from Fig. 4, to output print data to the image output device 52, the host device 51 performs image processing by collaborated operation among application software, an operating system and driver software in a layer structure.

In the present embodiment, processings individually depending on the image output devices are handled by device-specific drawing functions 31-1, 31-2, ..., 31-n, separated from a program for generally executing programs depending on individual implementations of image processing apparatus. Further, the core processing of driver software is independent of the individual image output devices.

A line-segmented image converted into a quantized amount is subjected to image processing by a color characteristic conversion module 33, a halftoning module 34 and the like. Further, a print command generation module 35 adds a command to the data and compresses the data, and delivers the generated data to the image output device 52 via a spooler 22 provided in the OS (Operating System).

As shown in Fig. 4, application software 11 is provided in the layer of application software, and a drawing processing interface 21 which receives a drawing command from the application software 11 and the spooler 22 which delivers the generated image data to the image output device 52 such as an ink-jet printer are provided in the layer of the OS (Operating System).

Then, the device-specific drawing functions 31-1, 31-2, ..., 31-n holding representation formats specific to the image output devices, the color characteristic conversion module 33 which receives line-segmented image information from the OS and which converts the color representation in the driver to a device-specific color representation, a halftoning module 34 which performs conversion to quantized amounts for representing respective pixel states of the device, and the print command generation module 35 which adds a command to the image output device 52 to the halftoning-processed image data, and outputs the data to the spooler 22, are provided in the layer of driver software.

Next, a particular example of image output from the application software to the image output device 52 will be described with reference to the flowchart of Fig. 5 showing the outline of the image processing together with Fig. 4.

When the application software 11 outputs an image to the image output device 52, first, the application

software 11 issues drawing commands to draw character(s), line(s), figure(s), bitmap(s) and the like, through the drawing processing interface 21 of the OS (step S1).

When the drawing commands for constructing an image frame/printing area have been completed (step S2), the OS converts the respective drawing commands in the internal format of the OS into a device-specific representation format (line-segmentation of respective drawing unit information) while calling the device-specific drawing functions 31-1, 31-2, ..., 31-n inside the driver software (step S3), thereafter, delivers the image information line-segmented from the image frame/printing area to the driver software (step S4).

Inside the driver software, the color characteristic conversion module 33 corrects the color characteristic of the device, and converts the color representation inside the driver software to that specific to the device (step S5), further, the halftoning module 34 performs conversion (halftoning) to a quantized amounts for representing respective pixel states of the device (step S6). Note that the conversion to quantized amount here corresponds to the form of data processed by the image output device 52. If printing by the image output device is performed based on e.g. binary data, binarization is performed, and if printing by the image output device is performed based on multivalue data (for printing by using thick/thin inks

and printing by using large-sized and small-sized ink droplets), the data is N-ary-converted.

The details of the halftoning will be described in the subsequent embodiments.

The print command generation module 35 receives quantized (binarized/N-ary-converted) image data (step S7). The print command generation module 35 processes the quantized image information in correspondence with the characteristic of the image output device by different methods. Further, the print command generation module 35 compresses the data and adds a command header to the data (step S8).

Thereafter, the print command generation module 35 forwards the generated data to the spooler 22 provided in the OS (step S9), to output the data to the image output device 52 (step S10).

Note that in the present embodiment, the above-described control method is realized by storing a program according to the flowchart of Fig. 5 into the storage device of the host device 51 and executing the program.

As described above, as the core processing of the driver software is independent of individual image output devices, the distribution of data processing between the driver software and the image output device can be flexibly changed without impairing the construction of the driver software. This is

advantageous in view of maintenance and management of the software.

Next, several embodiments using the system according to the above-described common embodiment will be described. In the following embodiments, the details of error diffusion processing performed by the halftoning module 34 will be described.

Note that the error diffusion processing to be described below handles multivalued image data where respective pixels are represented by respectively 8-bit (256 level representation) density data of yellow (Y) component, magenta (M) component, cyan (C) component and black (K) component.

[First Embodiment]

In this embodiment, error diffusion processing, different from the error diffusion processing of the conventional art, capable of complicated threshold condition processing will be described. The processing handles C and M component multivalued image data.

In the present embodiment, multivalued density data is binarized by the error diffusion processing.

Fig. 6 is a flowchart showing image formation control according to the first embodiment of the present invention.

Hereinbelow, the feature of the present embodiment will be described with reference to the flowchart.

First, at step S10, the density values Ct and Mt of the C and M components of pixel of interest are obtained as in the case of the conventional art. Next, at step S20, a threshold value (C threshold) used in error diffusion of the C component is obtained based on the obtained M component density value Mt. More specifically, in this embodiment, threshold tables as shown in Tables 1 and 2 are prepared in the HDD 2002 or the DRAM 1003 of the host device 52 in advance, and the threshold value is determined by referring to the threshold tables.

At step S30, the threshold value (C threshold) obtained at step S20 is compared with the density value Ct of the pixel of interest. If Ct≥C threshold holds, the process proceeds to step S40, at which setting is made for printing with C ink. Thereafter, the process proceeds to step S50. On the other hand, if Ct<C threshold holds at step S30, process skips step S40 and proceeds to step S50.

At step S50, a threshold value (M threshold) used in error diffusion of the M component is obtained based on the obtained C component density value Ct. More specifically, in this embodiment, the threshold tables as shown in Tables 1 and 2 are prepared in the HDD 2002 or the DRAM 1003 of the host device 52 in advance, and the threshold value is determined by referring to the threshold tables.

Accordingly, in this embodiment, both of the threshold tables as shown in Tables 1 and 2 are commonly used for the C component and the M component.

At step S60, the threshold value (M threshold) obtained at step S50 is compared with the density value Mt of the pixel of interest. If Mt≥M threshold holds, the process proceeds to step S70, at which setting is made for printing with M ink. Thereafter, the process ends. On the other hand, if Mt<M threshold holds at step S60, process skips step S70 and the proceeds ends.

Thus, by execution of the above processing, complicated threshold setting can be made only by defining threshold tables having a common format and setting different values in the tables, in the threshold condition processing as shown in Fig. 7A similar to the threshold processing according to the conventional art described in Fig. 24, and further, in the threshold condition processing as shown in Fig. 8A with threshold conditions more complicated than those in Fig. 7A.

Table 1 is a threshold table having threshold conditions corresponding to Fig. 7A, and Table 2, a threshold table having threshold conditions corresponding to Fig. 8A.

TABLE 1

DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE
0	128	64	64	128	128	192	191
1	127	65	65	129	129	193	190
2	126	66	66	130	130	194	189
3	125	67	67	131	131	195	188
4	124	68	68	132	132	196	187
5	123	69	69	133	133	197	186
6	122	70	70	134	134	198	185
7	121	71	71	135	135	199	184
8	120	72	72	136	136	200	183
9	119	73	73	137	137	201	182
10	118	74	74	138	138	202	181
11	117	75	75	139	139	203	180
12	116	76	76	140	140	204	179
13	115	77	77	141	141	205	178
14	114	78	78	142	142	206	177
15	113	79	79	143	143	207	176
16	112	80	80	144	144	208	175
17	111	81	81	145	145	209	174
18	110	82	82	146	146	210	173
19	109	83	83	147	147	211	172
20	108	84	84	148	148	212	171
21	107	85	85	149	149	213	170
22	106	86	86	150	150	214	169
23	105	87	87	151	151	215	168
24	104	88	88	152	152	216	167
25	103	89	89	153	153	217	166
26	102	90	90	154	154	218	165
27	101	91	91	155	155	219	164
28	100	92	92	156	156	220	163
29	99	93	93	157	157	221	162
30	98	94	94	158	158	222	161
31	97	95	95	159	159	223	160
32	96	96	96	160	160	224	159
33	95	97	97	161	161	225	158
34	94	98	98	162	162	226	157
35	93	99	99	163	163	227	156
36	92	100	100	164	164	228	155
37	91	101	101	165	165	229	154
38	90	102	102	166	166	230	153
39	89	103	103	167	167	231	152
40	88	104	104	168	168	232	151
41	87	105	105	169	169	233	150
42	86	106	106	170	170	234	149
43	85	107	107	171	171	235	148
44	84	108	108	172	172	236	147
45	83	109	109	173	173	237	146
46	82	110	110	174	174	238	145
47	81	111	111	175	175	239	144
48	80	112	112	176	176	240	143
49	79	113	113	177	177	241	142
50	78	114	114	178	178	242	141
51	77	115	115	179	179	243	140
52	76	116	116	180	180	244	139
53	75	117	117	181	181	245	138
54	74	118	118	182	182	246	137
55	73	119	119	183	183	247	136
56	72	120	120	184	184	248	135
57	71	121	121	185	185	249	134
58	70	122	122	186	186	250	133
59	69	123	123	187	187	251	132
60	68	124	124	188	188	252	131
61	67	125	125	189	189	253	130
62	66	126	126	190	190	254	129
63	65	127	127	191	191	255	128

TABLE 2

DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE
0	128	64	64	128	128	192	128
1	127	65	65	129	128	193	128
2	126	66	66	130	128	194	128
3	125	67	67	131	128	195	128
4	124	68	68	132	128	196	128
5	123	69	69	133	128	197	128
6	122	70	70	134	128	198	128
7	121	71	71	135	128	199	128
8	120	72	72	136	128	200	128
9	119	73	73	137	128	201	128
10	118	74	74	138	128	202	128
11	117	75	75	139	128	203	128
12	116	76	76	140	128	204	128
13	115	77	77	141	128	205	128
14	114	78	78	142	128	206	128
15	113	79	79	143	128	207	128
16	112	80	80	144	128	208	128
17	111	81	81	145	128	209	128
18	110	82	82	146	128	210	128
19	109	83	83	147	128	211	128
20	108	84	84	148	128	212	128
21	107	85	85	149	128	213	128
22	106	86	86	150	128	214	128
23	105	87	87	151	128	215	128
24	104	88	88	152	128	216	128
25	103	89	89	153	128	217	128
26	102	90	90	154	128	218	128
27	101	91	91	155	128	219	128
28	100	92	92	156	128	220	128
29	99	93	93	157	128	221	128
30	98	94	94	158	128	222	128
31	97	95	95	159	128	223	128
32	96	96	96	160	128	224	128
33	95	97	97	161	128	225	128
34	94	98	98	162	128	226	128
35	93	99	99	163	128	227	128
36	92	100	100	164	128	228	128
37	91	101	101	165	128	229	128
38	90	102	102	166	128	230	128
39	89	103	103	167	128	231	128
40	88	104	104	168	128	232	128
41	87	105	105	169	128	233	128
42	86	106	106	170	128	234	128
43	85	107	107	171	128	235	128
44	84	108	108	172	128	236	128
45	83	109	109	173	128	237	128
46	82	110	110	174	128	238	128
47	81	111	111	175	128	239	128
48	80	112	112	176	128	240	128
49	79	113	113	177	128	241	128
50	78	114	114	178	128	242	128
51	77	115	115	179	128	243	128
52	76	116	116	180	128	244	128
53	75	117	117	181	128	245	128
54	74	118	118	182	128	246	128
55	73	119	119	183	128	247	128
56	72	120	120	184	128	248	128
57	71	121	121	185	128	249	128
58	70	122	122	186	128	250	128
59	69	123	123	187	128	251	128
60	68	124	124	188	128	252	128
61	67	125	125	189	128	253	128
62	66	126	126	190	128	254	128
63	65	127	127	191	128	255	128

TABLE 3

DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE
0	85	64	64	128	43	192	107
1	84	65	65	129	44	193	108
2	83	66	66	130	45	194	109
3	82	67	67	131	46	195	110
4	81	68	68	132	47	196	111
5	80	69	69	133	48	197	112
6	79	70	70	134	49	198	113
7	78	71	71	135	50	199	114
8	77	72	72	136	51	200	115
9	76	73	73	137	52	201	116
10	75	74	74	138	53	202	117
11	74	75	75	139	54	203	118
12	73	76	76	140	55	204	119
13	72	77	77	141	56	205	120
14	71	78	78	142	57	206	121
15	70	79	79	143	58	207	122
16	69	80	80	144	59	208	123
17	68	81	81	145	60	209	124
18	67	82	82	146	61	210	125
19	66	83	83	147	62	211	126
20	65	84	84	148	63	212	127
21	64	85	85	149	64	213	127
22	63	86	84	150	65	214	126
23	62	87	83	151	66	215	125
24	61	88	82	152	67	216	124
25	60	89	81	153	68	217	123
26	59	90	80	154	69	218	122
27	58	91	79	155	70	219	121
28	57	92	78	156	71	220	120
29	56	93	77	157	72	221	119
30	55	94	76	158	73	222	118
31	54	95	75	159	74	223	117
32	53	96	74	160	75	224	116
33	52	97	73	161	76	225	115
34	51	98	72	162	77	226	114
35	50	99	71	163	78	227	113
36	49	100	70	164	79	228	112
37	48	101	69	165	80	229	111
38	47	102	68	166	81	230	110
39	46	103	67	167	82	231	109
40	45	104	66	168	83	232	108
41	44	105	65	169	84	233	107
42	43	106	64	170	85	234	106
43	43	107	63	171	86	235	105
44	44	108	62	172	87	236	104
45	45	109	61	173	88	237	103
46	46	110	60	174	89	238	102
47	47	111	59	175	90	239	101
48	48	112	58	176	91	240	100
49	49	113	57	177	92	241	99
50	50	114	56	178	93	242	98
51	51	115	55	179	94	243	97
52	52	116	54	180	95	244	96
53	53	117	53	181	96	245	95
54	54	118	52	182	97	246	94
55	55	119	51	183	98	247	93
56	56	120	50	184	99	248	92
57	57	121	49	185	100	249	91
58	58	122	48	186	101	250	90
59	59	123	47	187	102	251	89
60	60	124	46	188	103	252	88
61	61	125	45	189	104	253	87
62	62	126	44	190	105	254	86
63	63	127	43	191	106	255	85

TABLE 4

DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE
0	170	64	149	128	212	192	192
1	169	65	150	129	211	193	193
2	168	66	151	130	210	194	194
3	167	67	152	131	209	195	195
4	166	68	153	132	208	196	196
5	165	69	154	133	207	197	197
6	164	70	155	134	206	198	198
7	163	71	156	135	205	199	199
8	162	72	157	136	204	200	200
9	161	73	158	137	203	201	201
10	160	74	159	138	202	202	202
11	159	75	160	139	201	203	203
12	158	76	161	140	200	204	204
13	157	77	162	141	199	205	205
14	156	78	163	142	198	206	206
15	155	79	164	143	197	207	207
16	154	80	165	144	196	208	208
17	153	81	166	145	195	209	209
18	152	82	167	146	194	210	210
19	151	83	168	147	193	211	211
20	150	84	169	148	192	212	212
21	149	85	170	149	191	213	212
22	148	86	171	150	190	214	211
23	147	87	172	151	189	215	210
24	146	88	173	152	188	216	209
25	145	89	174	153	187	217	208
26	144	90	175	154	186	218	207
27	143	91	176	155	185	219	206
28	142	92	177	156	184	220	205
29	141	93	178	157	183	221	204
30	140	94	179	158	182	222	203
31	139	95	180	159	181	223	202
32	138	96	181	160	180	224	201
33	137	97	182	161	179	225	200
34	136	98	183	162	178	226	199
35	135	99	184	163	177	227	198
36	134	100	185	164	176	228	197
37	133	101	186	165	175	229	196
38	132	102	187	166	174	230	195
39	131	103	188	167	173	231	194
40	130	104	189	168	172	232	193
41	129	105	190	169	171	233	192
42	128	106	191	170	170	234	191
43	128	107	192	171	171	235	190
44	129	108	193	172	172	236	189
45	130	109	194	173	173	237	188
46	131	110	195	174	174	238	187
47	132	111	196	175	175	239	186
48	133	112	197	176	176	240	185
49	134	113	198	177	177	241	184
50	135	114	199	178	178	242	183
51	136	115	200	179	179	243	182
52	137	116	201	180	180	244	181
53	138	117	202	181	181	245	180
54	139	118	203	182	182	246	179
55	140	119	204	183	183	247	178
56	141	120	205	184	184	248	177
57	142	121	206	185	185	249	176
58	143	122	207	186	186	250	175
59	144	123	208	187	187	251	174
60	145	124	209	188	188	252	173
61	146	125	210	189	189	253	172
62	147	126	211	190	190	254	171
63	148	127	212	191	191	255	170

TABLE 5

DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE
0	85	64	64	128	85	192	85
1	84	65	65	129	85	193	85
2	83	66	66	130	85	194	85
3	82	67	67	131	85	195	85
4	81	68	68	132	85	196	85
5	80	69	69	133	85	197	85
6	79	70	70	134	85	198	85
7	78	71	71	135	85	199	85
8	77	72	72	136	85	200	85
9	76	73	73	137	85	201	85
10	75	74	74	138	85	202	85
11	74	75	75	139	85	203	85
12	73	76	76	140	85	204	85
13	72	77	77	141	85	205	85
14	71	78	78	142	85	206	85
15	70	79	79	143	85	207	85
16	69	80	80	144	85	208	85
17	68	81	81	145	85	209	85
18	67	82	82	146	85	210	85
19	66	83	83	147	85	211	85
20	65	84	84	148	85	212	85
21	64	85	85	149	85	213	85
22	63	86	85	150	85	214	85
23	62	87	85	151	85	215	85
24	61	88	85	152	85	216	85
25	60	89	85	153	85	217	85
26	59	90	85	154	85	218	85
27	58	91	85	155	85	219	85
28	57	92	85	156	85	220	85
29	56	93	85	157	85	221	85
30	55	94	85	158	85	222	85
31	54	95	85	159	85	223	85
32	53	96	85	160	85	224	85
33	52	97	85	161	85	225	85
34	51	98	85	162	85	226	85
35	50	99	85	163	85	227	85
36	49	100	85	164	85	228	85
37	48	101	85	165	85	229	85
38	47	102	85	166	85	230	85
39	46	103	85	167	85	231	85
40	45	104	85	168	85	232	85
41	44	105	85	169	85	233	85
42	43	106	85	170	85	234	85
43	43	107	85	171	85	235	85
44	44	108	85	172	85	236	85
45	45	109	85	173	85	237	85
46	46	110	85	174	85	238	85
47	47	111	85	175	85	239	85
48	48	112	85	176	85	240	85
49	49	113	85	177	85	241	85
50	50	114	85	178	85	242	85
51	51	115	85	179	85	243	85
52	52	116	85	180	85	244	85
53	53	117	85	181	85	245	85
54	54	118	85	182	85	246	85
55	55	119	85	183	85	247	85
56	56	120	85	184	85	248	85
57	57	121	85	185	85	249	85
58	58	122	85	186	85	250	85
59	59	123	85	187	85	251	85
60	60	124	85	188	85	252	85
61	61	125	85	189	85	253	85
62	62	126	85	190	85	254	85
63	63	127	85	191	85	255	85

TABLE 6

DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE
0	170	64	170	128	170	192	170
1	170	65	170	129	170	193	170
2	170	66	170	130	170	194	170
3	170	67	170	131	170	195	170
4	170	68	170	132	170	196	170
5	170	69	170	133	170	197	170
6	170	70	170	134	170	198	170
7	170	71	170	135	170	199	170
8	170	72	170	136	170	200	170
9	170	73	170	137	170	201	170
10	170	74	170	138	170	202	170
11	170	75	170	139	170	203	170
12	170	76	170	140	170	204	170
13	170	77	170	141	170	205	170
14	170	78	170	142	170	206	170
15	170	79	170	143	170	207	170
16	170	80	170	144	170	208	170
17	170	81	170	145	170	209	170
18	170	82	170	146	170	210	170
19	170	83	170	147	170	211	170
20	170	84	170	148	170	212	170
21	170	85	170	149	170	213	170
22	170	86	170	150	170	214	170
23	170	87	170	151	170	215	170
24	170	88	170	152	170	216	170
25	170	89	170	153	170	217	170
26	170	90	170	154	170	218	170
27	170	91	170	155	170	219	170
28	170	92	170	156	170	220	170
29	170	93	170	157	170	221	170
30	170	94	170	158	170	222	170
31	170	95	170	159	170	223	170
32	170	96	170	160	170	224	170
33	170	97	170	161	170	225	170
34	170	98	170	162	170	226	170
35	170	99	170	163	170	227	170
36	170	100	170	164	170	228	170
37	170	101	170	165	170	229	170
38	170	102	170	166	170	230	170
39	170	103	170	167	170	231	170
40	170	104	170	168	170	232	170
41	170	105	170	169	170	233	170
42	170	106	170	170	170	234	170
43	170	107	170	171	170	235	170
44	170	108	170	172	170	236	170
45	170	109	170	173	170	237	170
46	170	110	170	174	170	238	170
47	170	111	170	175	170	239	170
48	170	112	170	176	170	240	170
49	170	113	170	177	170	241	170
50	170	114	170	178	170	242	170
51	170	115	170	179	170	243	170
52	170	116	170	180	170	244	170
53	170	117	170	181	170	245	170
54	170	118	170	182	170	246	170
55	170	119	170	183	170	247	170
56	170	120	170	184	170	248	170
57	170	121	170	185	170	249	170
58	170	122	170	186	170	250	170
59	170	123	170	187	170	251	170
60	170	124	170	188	170	252	170
61	170	125	170	189	170	253	170
62	170	126	170	190	170	254	170
63	170	127	170	191	170	255	170

TABLE 8

DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE
0	128	64	110	128	128	192	143
1	127	65	110	129	129	193	143
2	127	66	109	130	130	194	142
3	127	67	109	131	131	195	141
4	127	68	108	132	132	196	141
5	127	69	107	133	133	197	140
6	127	70	107	134	134	198	140
7	127	71	106	135	135	199	139
8	127	72	105	136	136	200	139
9	127	73	105	137	137	201	138
10	127	74	104	138	138	202	138
11	127	75	103	139	139	203	138
12	127	76	102	140	140	204	137
13	127	77	102	141	141	205	137
14	127	78	101	142	142	206	136
15	127	79	100	143	143	207	136
16	126	80	99	144	144	208	135
17	126	81	99	145	145	209	135
18	126	82	98	146	146	210	135
19	126	83	97	147	147	211	134
20	126	84	96	148	148	212	134
21	126	85	95	149	149	213	134
22	126	86	94	150	150	214	133
23	125	87	93	151	151	215	133
24	125	88	92	152	152	216	133
25	125	89	91	153	153	217	132
26	125	90	91	154	154	218	132
27	125	91	91	155	155	219	132
28	124	92	92	156	156	220	131
29	124	93	93	157	157	221	131
30	124	94	94	158	158	222	131
31	124	95	95	159	159	223	131
32	123	96	96	160	160	224	130
33	123	97	97	161	161	225	130
34	123	98	98	162	162	226	130
35	123	99	99	163	163	227	130
36	122	100	100	164	164	228	129
37	122	101	101	165	163	229	129
38	122	102	102	166	163	230	129
39	121	103	103	167	162	231	129
40	121	104	104	168	161	232	129
41	121	105	105	169	160	233	128
42	120	106	106	170	159	234	128
43	120	107	107	171	158	235	128
44	120	108	108	172	157	236	128
45	119	109	109	173	156	237	128
46	119	110	110	174	155	238	128
47	119	111	111	175	155	239	128
48	118	112	112	176	154	240	127
49	118	113	113	177	153	241	127
50	117	114	114	178	152	242	127
51	117	115	115	179	152	243	127
52	116	116	116	180	151	244	127
53	116	117	117	181	150	245	127
54	116	118	118	182	149	246	127
55	115	119	119	183	149	247	127
56	115	120	120	184	148	248	127
57	114	121	121	185	147	249	127
58	114	122	122	186	147	250	127
59	113	123	123	187	146	251	127
60	113	124	124	188	145	252	127
61	112	125	125	189	145	253	127
62	111	126	126	190	144	254	127
63	111	127	127	191	144	255	127

In a case where an ink-jet printer having a slightly greater ink discharge amount is used as the image output device, isolated dots formed by the C or M ink are easily recognized in a very low density image area, and the uniformity of the image is impaired by exclusive arrangement of these dots, if the above threshold conditions are used, the correlation between the C component and the M component can be slightly lowered and the uniformity of the image can be maintained.

(2) As shown in Fig. 9B, threshold conditions overlapped with noise are employed. Table 9 is a threshold table used in this case.

TABLE 9

DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE
0	130	64	66	128	130	192	193
1	127	65	65	129	129	193	190
2	124	66	64	130	128	194	187
3	125	67	67	131	131	195	188
4	126	68	70	132	134	196	189
5	123	69	69	133	133	197	186
6	120	70	68	134	132	198	183
7	121	71	71	135	135	199	184
8	122	72	74	136	138	200	185
9	119	73	73	137	137	201	182
10	116	74	72	138	136	202	179
11	117	75	75	139	139	203	180
12	116	76	78	140	142	204	181
13	115	77	77	141	141	205	178
14	112	78	76	142	140	206	175
15	113	79	79	143	143	207	176
16	114	80	82	144	146	208	177
17	111	81	81	145	145	209	174
18	108	82	80	146	144	210	171
19	109	83	83	147	147	211	172
20	110	84	86	148	150	212	173
21	107	85	85	149	149	213	170
22	104	86	84	150	148	214	167
23	105	87	87	151	151	215	168
24	106	88	90	152	154	216	169
25	103	89	89	153	153	217	166
26	100	90	88	154	152	218	163
27	101	91	91	155	155	219	164
28	102	92	94	156	158	220	165
29	99	93	93	157	157	221	162
30	96	94	92	158	156	222	159
31	97	95	95	159	159	223	160
32	98	96	98	160	162	224	161
33	95	97	97	161	161	225	158
34	92	98	96	162	160	226	155
35	93	99	99	163	163	227	156
36	94	100	102	164	166	228	157
37	91	101	101	165	165	229	154
38	88	102	100	166	164	230	151
39	89	103	103	167	167	231	152
40	90	104	106	168	170	232	153
41	87	105	105	169	169	233	150
42	84	106	104	170	168	234	147
43	85	107	107	171	171	235	148
44	86	108	110	172	174	236	149
45	83	109	109	173	173	237	146
46	80	110	108	174	172	238	143
47	81	111	111	175	175	239	144
48	82	112	114	176	178	240	145
49	79	113	113	177	177	241	142
50	76	114	112	178	176	242	139
51	77	115	115	179	179	243	140
52	78	116	118	180	182	244	141
53	75	117	117	181	181	245	138
54	72	118	116	182	180	246	135
55	73	119	119	183	183	247	136
56	74	120	122	184	186	248	137
57	71	121	121	185	185	249	134
58	68	122	120	186	184	250	131
59	69	123	123	187	187	251	132
60	70	124	126	188	190	252	133
61	67	125	125	189	189	253	130
62	64	126	124	190	188	254	127
63	65	127	127	191	191	255	128

TABLE 10

DENSITY	MULTIVALUE OUTPUT VALUE	DENSITY	MULTIVALUE OUTPUT VALUE	DENSITY	MULTIVALUE OUTPUT VALUE	DENSITY	MULTIVALUE OUTPUT VALUE
0	0	64	0	128	1	192	2
1	0	65	0	129	1	193	2
2	0	66	0	130	1	194	2
3	0	67	0	131	1	195	2
4	0	68	0	132	1	196	2
5	0	69	0	133	1	197	2
6	0	70	0	134	1	198	2
7	0	71	0	135	1	199	2
8	0	72	0	136	1	200	2
9	0	73	0	137	1	201	2
10	0	74	0	138	1	202	2
11	0	75	0	139	1	203	2
12	0	76	0	140	1	204	2
13	0	77	0	141	1	205	2
14	0	78	0	142	1	206	2
15	0	79	0	143	1	207	2
16	0	80	0	144	1	208	2
17	0	81	0	145	1	209	2
18	0	82	0	146	1	210	2
19	0	83	0	147	1	211	2
20	0	84	0	148	1	212	2
21	0	85	1	149	1	213	2
22	0	86	1	150	1	214	2
23	0	87	1	151	1	215	2
24	0	88	1	152	1	216	2
25	0	89	1	153	1	217	2
26	0	90	1	154	1	218	2
27	0	91	1	155	1	219	2
28	0	92	1	156	1	220	2
29	0	93	1	157	1	221	2
30	0	94	1	158	1	222	2
31	0	95	1	159	1	223	2
32	0	96	1	160	1	224	2
33	0	97	1	161	1	225	2
34	0	98	1	162	1	226	2
35	0	99	1	163	1	227	2
36	0	100	1	164	1	228	2
37	0	101	1	165	1	229	2
38	0	102	1	166	1	230	2
39	0	103	1	167	1	231	2
40	0	104	1	168	1	232	2
41	0	105	1	169	1	233	2
42	0	106	1	170	2	234	2
43	0	107	1	171	2	235	2
44	0	108	1	172	2	236	2
45	0	109	1	173	2	237	2
46	0	110	1	174	2	238	2
47	0	111	1	175	2	239	2
48	0	112	1	176	2	240	2
49	0	113	1	177	2	241	2
50	0	114	1	178	2	242	2
51	0	115	1	179	2	243	2
52	0	116	1	180	2	244	2
53	0	117	1	181	2	245	2
54	0	118	1	182	2	246	2
55	0	119	1	183	2	247	2
56	0	120	1	184	2	248	2
57	0	121	1	185	2	249	2
58	0	122	1	186	2	250	2
59	0	123	1	187	2	251	2
60	0	124	1	188	2	252	2
61	0	125	1	189	2	253	2
62	0	126	1	190	2	254	2
63	0	127	1	191	2	255	2

For example, in a case where the threshold condition processing as shown in Fig. 7A is performed in accordance with the present embodiment, first, at steps S20 to S40, the threshold condition processing as shown in Fig. 7B is performed, then at steps S50 to S70, the threshold condition processing as shown in Fig. 7C is performed.

Similarly, in a case where the threshold condition processing as shown in Fig. 8A is performed in accordance with the present embodiment, first, at steps S20 to S40, the threshold condition processing as shown in Fig. 8B is performed, then at steps S50 to S70, the threshold condition processing as shown in Fig. 8C is performed.

Accordingly, in the above-described embodiment, as the threshold condition processing is performed by using a predetermined format threshold table, even if the threshold conditions are complicated as shown in Figs. 9A to 9D, the processing can be performed in a simple manner, and as the processing is simple, the complicated threshold condition processing can be performed at a high speed.

[Second Embodiment]

In the first embodiment, the multivalued density data is binarized by the error diffusion processing; in

the present embodiment, multivalued density data is ternarized by the error diffusion processing.

Fig. 10 is a flowchart showing the image formation control according to the second embodiment of the present invention.

Hereinbelow, the feature of the present embodiment will be described with reference to the flowchart.

First, at step S100, the density values Ct and Mt of the C and M components of the pixel of interest are obtained as in the case of the conventional art. Next, at step S110, two threshold values (C threshold1 and C threshold2) used in error diffusion of the C component are obtained based on the obtained M component density value Mt. More specifically, in this embodiment, the threshold tables as shown in Tables 3 to 6 are prepared in the HDD 2002 or the DRAM 1003 of the host device 52 in advance, and the threshold values are determined by referring to the threshold tables.

At step S120, one of the threshold values (C threshold1) obtained at step S110 is compared with the density value Ct of the pixel of interest. If Ct≥C threshold1 holds, the process proceeds to step S130, at which the other threshold value (C threshold2) obtained at step S110 is compared with the density value Ct of the pixel of interest. If Ct≥C threshold2 holds, the process proceeds to step S140, at which setting is made for printing by discharging large ink droplets using the

C ink. Thereafter, the process proceeds to step S160. On the other hand, if $Ct<C$ threshold2 holds at step S130, the process proceeds to step S150, at which setting is made for printing by discharging small ink droplets using the C ink. Thereafter, the process proceeds to step S160.

Further, if $Ct<C$ threshold1 holds at step S120, the process skips steps S130 to S150 and proceeds to step S160.

At step S160, two threshold values (M threshold1 and M threshold2) used in error diffusion of the M component are obtained based on the obtained C component density value Ct. More specifically, in this embodiment, the threshold tables as shown in Tables 3 to 6 are prepared in the HDD 2002 or the DRAM 1003 of the host device 52 in advance, and the threshold values are determined by referring to the threshold tables.

Accordingly, in this embodiment, the threshold tables in Tables 3 to 6 are commonly used for the C component and the M component.

At step S170, one of the threshold values (M threshold1) obtained at step S160 is compared with the density value Mt of the pixel of interest. If $Mt \geq M$ threshold1 holds, the process proceeds to step S180, at which the other threshold value (M threshold2) obtained at step S160 is compared with the density value Mt of the pixel of interest. If $Mt \geq M$ threshold2 holds, the

process proceeds to step S190, at which setting is made for printing by discharging large ink droplets using the M ink. Then, the process ends. On the other hand, if Mt<M threshold2 holds at step S180, the process proceeds to step S200, at which setting is made for printing by discharging small ink droplets using the M ink. Then the process ends.

On the other hand, if Mt<M threshold1 holds at step S170, the process skips steps S180 to S200 and the process ends.

Thus, by execution of the above processing, complicated threshold setting can easily be made only by defining threshold tables having a common format and setting different values in the tables, in the threshold condition processing as shown in Fig. 11A, and further, in the threshold condition processing as shown in Fig. 12A.

Tables 3 and 4 are threshold tables having threshold conditions corresponding to Fig. 11A, and Tables 5 and 6, threshold tables having threshold conditions corresponding to Fig. 12A.

For example, in a case where the threshold condition processing as shown in Fig. 11A is performed in accordance with the present embodiment, first, at steps S110 to S150, the threshold condition processing as shown in Fig. 11B is performed, then at steps S160 to S200, the threshold condition processing as shown in Fig. 11C is performed.

Similarly, in a case where the threshold condition processing as shown in Fig. 12A is performed in accordance with the present embodiment, first, at steps S110 to S150, the threshold condition processing as shown in Fig. 12B is performed, then at steps S160 to S200, the threshold condition processing as shown in Fig. 12C is performed. Especially, the threshold conditions shown in Figs. 12A to 12C are effective for improvement in uniformity of halftone image.

Accordingly, in the above-described embodiment, even in ternarization of multivalued image data, as the threshold condition processing is performed by using a predetermined format threshold table, even if the threshold conditions are complicated, the processing can be performed in a simple manner, and as the processing is simple, the complicated threshold condition processing can be performed at a high speed.

Note that in the present embodiment, only ternarization is handled, however, if the ink-jet printer as the image output device is capable of

handling quaternary or quinary representation by using drop modulation and same-color various density ink (e.g. thin cyan ink, thick cyan ink, thin magenta ink and thick magenta ink), threshold tables for multivalue error diffusion processing such as quaternarization or quinarization may be generated.

[Third Embodiment]

In the first and second embodiments, the C and M components among the multivalued density data are handled; in the present embodiment, the K component in addition to these components is handled.

Fig. 13 is a flowchart showing the image formation control according to the third embodiment of the present invention.

Hereinbelow, the feature of the present embodiment will be described with reference to the flowchart.

First, at step S210, the density values Ct, Mt and Kt of the C, M and K components of pixel of interest are obtained. Next, at step S220, a threshold value (C threshold) used in error diffusion of the C component is obtained based on the obtained M and K component density values Mt and Kt. More specifically, in this embodiment, a threshold table as shown in Table 7 is prepared in the HDD 2002 or the DRAM 1003 of the host device 52 in advance, and the threshold value is determined by referring to the threshold table.

At step S230, the threshold value (C threshold) obtained at step S220 is compared with the density value Ct of the pixel of interest. If $Ct \geq C$ threshold holds, the process proceeds to step S240, at which setting is made for printing with the C ink. Thereafter, the process proceeds to step S250. On the other hand, if $Ct < C$ threshold holds at step S230, process skips step S240 and proceeds to step S250.

At step S250, a threshold value (M threshold) used in error diffusion of the M component is obtained based on the obtained C and K component density values Ct and Kt. More specifically, in this embodiment, a threshold table as shown in Table 7 is prepared in the HDD 2002 or the DRAM 1003 of the host device 52 in advance, and the threshold value is determined by referring to the threshold table.

At step S260, the threshold value (M threshold) obtained at step S250 is compared with the density value Mt of the pixel of interest. If $Mt \geq M$ threshold holds, the process proceeds to step S270, at which setting is made for printing with the M ink. Thereafter, the process proceeds to step S280. On the other hand, if $Mt < M$ threshold holds at step S260, the process skips step S270 and proceeds to step S280.

Further, at step S280, a threshold value (K threshold) used in error diffusion of the K component is obtained based on the obtained C and M component density

values Ct and Mt. More specifically, in this embodiment, a threshold table as shown in Table 7 is prepared in the HDD 2002 or the DRAM 1003 of the host device 52 in advance, and the threshold value is determined by referring to the threshold table.

Accordingly, in this embodiment, the threshold table in Table 7 is commonly used for the C component, the M component and the K component.

At step S290, the threshold value (K threshold) obtained at step S280 is compared with the density value Kt of the pixel of interest. If Kt≥K threshold holds, the process proceeds to step S300, at which setting is made for printing with K ink. Then, the process ends. On the other hand, if Kt<K threshold holds, the process skips step S300 and the process ends.

The code representing the core part of the above processing is as follows.

```
 Ct=C+Cerr
 Mt=M+Merr
 Kt=K+Kerr
 Cthreshold=C_Threshold_Table[Mt+Kt]
 If(Ct>=Cthreshold)
Print C
 Mthreshold=M_Threshold_Table[Ct+Kt]
 If(Mt>=Mthreshold)
Print M
 Kthreshold=M_Threshold_Table[Ct+Mt]
```

```
If(Kt>=Kthreshold)
Print K
```

By executing the above processing, the threshold condition processing for three components, which is complicated in the conventional art as explained by using program code, can easily be performed only by defining a threshold table having a common format and setting different values in the threshold table.

Table 7 is a threshold table commonly used for the C, M and K components.

TABLE 7

DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE	DENSITY	THRESHOLD VALUE
0	128	64	64	128	128	192	128
1	127	65	65	129	128	193	128
2	126	66	66	130	128	194	128
3	125	67	67	131	128	195	128
4	124	68	68	132	128	196	128
5	123	69	69	133	128	197	128
6	122	70	70	134	128	198	128
7	121	71	71	135	128	199	128
8	120	72	72	136	128	200	128
9	119	73	73	137	128	201	128
10	118	74	74	138	128	202	128
11	117	75	75	139	128	203	128
12	116	76	76	140	128	204	128
13	115	77	77	141	128	205	128
14	114	78	78	142	128	206	128
15	113	79	79	143	128	207	128
16	112	80	80	144	128	208	128
17	111	81	81	145	128	209	128
18	110	82	82	146	128	210	128
19	109	83	83	147	128	211	128
20	108	84	84	148	128	212	128
21	107	85	85	149	128	213	128
22	106	86	86	150	128	214	128
23	105	87	87	151	128	215	128
24	104	88	88	152	128	216	128
25	103	89	89	153	128	217	128
26	102	90	90	154	128	218	128
27	101	91	91	155	128	219	128
28	100	92	92	156	128	220	128
29	99	93	93	157	128	221	128
30	98	94	94	158	128	222	128
31	97	95	95	159	128	223	128
32	96	96	96	160	128	224	128
33	95	97	97	161	128	225	128
34	94	98	98	162	128	226	128
35	93	99	99	163	128	227	128
36	92	100	100	164	128	228	128
37	91	101	101	165	128	229	128
38	90	102	102	166	128	230	128
39	89	103	103	167	128	231	128
40	88	104	104	168	128	232	128
41	87	105	105	169	128	233	128
42	86	106	106	170	128	234	128
43	85	107	107	171	128	235	128
44	84	108	108	172	128	236	128
45	83	109	109	173	128	237	128
46	82	110	110	174	128	238	128
47	81	111	111	175	128	239	128
48	80	112	112	176	128	240	128
49	79	113	113	177	128	241	128
50	78	114	114	178	128	242	128
51	77	115	115	179	128	243	128
52	76	116	116	180	128	244	128
53	75	117	117	181	128	245	128
54	74	118	118	182	128	246	128
55	73	119	119	183	128	247	128
56	72	120	120	184	128	248	128
57	71	121	121	185	128	249	128
58	70	122	122	186	128	250	128
59	69	123	123	187	128	251	128
60	68	124	124	188	128	252	128
61	67	125	125	189	128	253	128
62	66	126	126	190	128	254	128
63	65	127	127	191	128	255	128

Accordingly, in the above-described embodiment, as the threshold conditional processing is performed by using a predetermined format threshold table, even the error diffusion processing handling three components with complicated threshold conditions can be performed in a simple manner, and as the processing is simple, the complicated threshold condition processing can be performed at a high speed.

Further, if the present embodiment is combined with the ternarization processing of the second embodiment, the advantages of simplification and increase in processing speed can be further improved.

Note that the present invention is not limited to the threshold tables described in the above-described embodiments. If the format of the threshold table is maintained while the values set in the table are changed, processing can be performed with various threshold conditions as follows.

(1) instead of the sum of the C and M component density values (C+M), threshold conditions such as the sum of squares of the C and M component density values (C^2+M^2) are employed. Table 8 is a threshold table used in this case.

By using the threshold conditions, the probability of formation of continuous C-ink or M-ink dots can be reduced.

(3) As shown in Fig. 9C, the tendency of error diffusion is changed in a highlight area and intermediate to high density areas. By using the threshold conditions, the degradation of image quality due to fluctuation of ink dot application position can be reduced.

(4) As shown in Fig. 9D, the boundaries of thresholds are smoothed as much as possible. By using such threshold conditions, the abrupt change can be reduced between an area where C and M inks are exclusively used and an area where the C and M inks are not exclusively used, and capability of representing an image can be improved.

In this manner, the threshold condition processing has flexibility by use of a threshold table. If the threshold table is used in combination with actual ink discharge amount or ink composition in the ink-jet printer, the content of image formation processing and/or purpose of the processing can be easily changed.

[Fourth Embodiment]

Further, assume that the ink-jet printer IJRA can handle multivalued image data by using drop modulation and/or same-color thick and thin inks (e.g., thin cyan ink, thick cyan ink, thin magenta ink and thick magenta ink).

In the present embodiment, unlike the conventional art, multivalued density data is ternarized by the error diffusion processing. The data handled by the error diffusion processing according to this embodiment is C component and M component multivalued image data.

Fig. 14 is a flowchart showing the image formation control according to the fourth embodiment of the present invention.

Hereinbelow, the feature of the present embodiment will be described with reference to the flowchart.

First, at step S310, the density values Ct and Mt of the C and M components of pixel of interest are obtained as in the case of the conventional art. Next, at step S320, it is determined whether or not the sum of the obtained M component density value Mt and the C component density value Ct is greater than a first threshold value (Threshold1). If Ct+Mt>Threshold1 holds, the process proceeds to step S330, at which it is determined whether or not the sum of the M component density value Mt and the C component density value Ct is less than a second threshold value (Threshold2). On the

other hand, if $Ct+Mt \leq \text{Threshold1}$ holds at step S320, the process ends.

At step S330, if $Ct+Mt < \text{Threshold2}$ holds, the process proceeds to step S340, at which the M component density value Mt and the C component density value Ct are compared with each other. If $Ct > Mt$ holds, the process proceeds to step S350, at which setting is made for printing with small-sized C ink droplet (or thin C ink). On the other hand, if $Ct \leq Mt$ holds, the process proceeds to step S360, at which setting is made for printing with small-sized M ink droplet (or thin M ink). After step S350 or S360, the process ends.

At step S330, if $Ct+Mt \geq \text{Threshold2}$ holds, the process proceeds to step S370, at which it is determined whether or not the sum of the M component density value Mt and the C component density value Ct is less than a third threshold value (Threshold3). If $Ct+Mt < \text{Threshold3}$ holds, the process proceeds to step S380, at which it is determined whether or not the difference between the M component density value Mt and the C component density value Ct is greater than a predetermined offset value (Offset1). If $Ct-Mt > \text{Offset1}$ holds, the process proceeds to step S390, at which setting is made for printing with large-sized C ink droplet (or thick C ink). Then, the process ends. On the other hand, if $Ct-Mt \leq \text{Offset1}$ holds, the process proceeds to step S400.

At step S400, it is determined whether or not the difference between the M component density value Mt and the C component density value Ct is greater than a predetermined offset value (Offset2). If $Mt-Ct \leq Offset2$ holds, the process proceeds to step S410, at which setting is made for printing with small-sized C ink droplet (or thin C ink) and small-sized M ink droplet (or thin M ink). Then, the process ends. On the other hand, if $Mt-Ct>Offset2$ holds, the process proceeds to step S420, at which setting is made for printing with large-sized M ink droplet (or thick M ink). Then, the process ends.

Further, at step S370, if $Ct+Mt \geq Threshold3$ holds, the process proceeds to step S430, at which it is determined whether or not the sum of the M component density value Mt and the C component density value Ct is less than a fourth threshold value (Threshold4). If $Ct+Mt<Threshold4$ holds, the process proceeds to step S440, at which the M component density value Mt and the C component density value Ct are compared with each other. If $Ct>Mt$ holds, the process proceeds to step S450, at which setting is made for printing with large-sized C ink droplet (or thick C ink) and small-sized M ink droplet (or thin M ink). Then the process ends. On the other hand, if $Ct \leq Mt$ holds, the process proceeds to step S460, at which setting is made for printing with small-

sized C ink droplet (or thin C ink) and large-sized M ink droplet (or thick M ink). Then, the process ends.

On the other hand, at step S430, if Ct+Mt≥Threshold4 holds, the process proceeds to step S470, at which setting is made for printing with large-sized C ink droplet (or thick C ink) and large-sized M ink droplet (or thick M ink). Then, the process ends.

Fig. 15 shows the threshold conditions for the C and M components in the processing shown in Fig. 14.

In the above-described processing, the following dot arrangements are made in accordance with the M component density value Mt and the C component density value Ct.

(1) Ct+Mt≤Threshold1

(C and M components belong to low density area → area (a) in Fig. 15)

Dot printing is not performed.

(2) Ct+Mt>Threshold1 and Ct+Mt<Threshold2 and Ct>Mt

(C component belongs to intermediate density area → area (b) in Fig. 15)

Dot printing with small-sized C ink droplet (or thin C ink)(exclusive printing).

(3) Ct+Mt>Threshold1 and Ct+Mt<Threshold2 and Ct≤Mt

(M component belongs to intermediate density area → area (c) in Fig. 15)

Dot printing with small-sized M ink droplet (or thin M ink)(exclusive printing).

(4) Ct+Mt>Threshold1 and Ct+Mt≥Threshold2 and Ct+Mt<Threshold3 and Ct-Mt>Offset1

(C component belongs to high density area → area (d) in Fig. 15)

Dot printing with large-sized C ink droplet (or thick C ink)(exclusive printing).

(5) Ct+Mt>Threshold1 and Ct+Mt≥Threshold2 and Ct+Mt<Threshold3 and Ct-Mt≤Offset1 and Mt-Ct≤Offset2

(C and M components belong to intermediate density area → area (e) in Fig. 15)

Dot printing with small-sized C ink droplet (or thin C ink) and small-sized M ink droplet (or thin M ink) (overlay printing).

(6) Ct+Mt>Threshold1 and Ct+Mt≥Threshold2 and Ct+Mt<Threshold3 and Mt-Ct≤Offset1 and Mt-Ct>Offset2

(M component belongs to high density area → area (f) in Fig. 15)

Dot printing with large-sized M ink droplet (or thick M ink)(exclusive printing).

(7) Ct+Mt>Threshold1 and Ct+Mt≥Threshold2 and Ct+Mt≥Threshold3 and Ct+Mt<Threshold4 and Ct>Mt

(C component belongs to high density area and M component belongs to intermediate density area → area (g) in Fig. 15)

Dot printing with large-sized C ink droplet (or thick C ink) and small-sized M ink droplet (or thin M ink)(overlay printing).

(8) Ct+Mt>Threshold1 and Ct+Mt≥Threshold2 and Ct+Mt≥Threshold3 and Ct+Mt<Threshold4 and Ct≤Mt

(C component belongs to intermediate density area and M component belongs to high density area → area (h) in Fig. 15)

Dot printing with small-sized C ink droplet (or thin C ink) and large-sized M ink droplet (or thick M ink) (overlay printing).

(9) Ct+Mt≥Threshold4 (>Threshold3>Threshold2>Threshold1)

(C and M components belong to high density area → area (i) in Fig. 15)

Dot printing with large-sized C ink droplet (or thick C ink) and large-sized M ink droplet (or thick M ink) (overlay printing).

Accordingly, in the above-described present embodiment, as the printing with the M ink and C ink is changed in accordance with the C component and M

component density values, printing with reduced graininess can be performed by ternarizing the C component and M component density values and exclusively arranging printed dots based on the ternarization.

[Fifth Embodiment]

In the fourth embodiment, the multivalued density data is ternarized by the error diffusion processing; in the present embodiment, an example of high-speed processing in consideration of conversion of multivalued density data into N-ary code (N≥4) by the error diffusion will be described.

As it is apparent from the flowchart of Fig. 14 described in the first embodiment, in the case of ternarization, the C and M components are respectively ternarized, 9 (=3×3) arrangements are considered and branching processings by 8 "if" statements (condition statements) are required. That is, in the case of converting into N-ary code, N^2-1 "if" statements are required. Accordingly, as the value of N increases, processing time increases.

Fig. 16 is a flowchart showing the image formation control according to the fifth embodiment of the present invention.

Hereinbelow, the feature of the present embodiment will be described with reference to the flowchart.

In the present embodiment, as the threshold condition processing is very complicated in the conversion of input multivalued image data into N-ary code ($N \geq 3$) by the error diffusion processing, the conversion is made by the following procedure.

(1) Functions defined as X=Ct+Mt and Y=Ct-Mt are introduced for execution of multivalue error diffusion.

(2) A two-dimensional table is referred to based on the result of multivalue error diffusion processing, so as to determine arrangement of dots to be printed and dot type. The two-dimensional table may be a common table for the C and M components, however, actually, it is preferable that tables (C_Table and M_Table) respectively for the C and M components are prepared.

Returning to Fig. 16, first, at step S510, X and Y values are determined from density values of the C and M components in each pixel.

Next, at step S520, arguments (X_index, Y_index) of the above-described two-dimensional table are determined based on the X and Y values. In this embodiment, the arguments are determined as X and Y functions (X_index=f(X), Y_index=g(Y)).

Finally, at step S530, the two-dimensional table is referred to by using the arguments determined at step S520, and output values by the error diffusion processing of the C and M components (C out, M out) are determined.

For comparison, an example of ternarization processing the same as that described in the fourth embodiment, in accordance with the present embodiment, will be described.

Fig. 17 shows the ternarization according to the fifth embodiment.

Fig. 17 shows quaternarization of $X=Ct(=C+Cerr)+Mt(=M+Merr)$ and quinarization of $Y=Ct(=C+Cerr)-Mt(=M+Merr)$.

In Fig. 17, a right-upward straight line indicates the same X value (=Ct-Mt), and a left-upward straight line, the same Y value (=Ct+Mt) (Ct and Mt have variation widths of about $-128\leq Ct, Mt\leq 383$ including error-accumulation).

Accordingly, as the values Ct and Mt have the above variation widths, the X value has a variation width of about $-256\leq X\leq 766$, and the Y value, a variation width of about $-511\leq Y\leq 511$. To quaternarize and quinarize the X and Y values having the above variation widths, the function of X (f(X)) and that of Y (g(Y)) are introduced.

That is, X_index=f(X) and Y_index=g(Y) are calculated. The calculations can be realized by referring to the table.

In this manner, two additions and two multivalue conversion calculations (referring to the table) divide

the entire X and Y range into quaternary×quinary=20 sections.

In comparison between Figs. 17 and 15, the areas (a), (b), (c), (e), (g), (h) and (i) in Fig. 15 are respectively 2 sections in Fig. 17. The entire partitioning is approximately common to Figs. 15 and 17.

Accordingly, print control based on the error-diffusion processing by C and M ternarization can be performed by referring to a common two-dimensional table as shown in Fig. 18 based on the results of X and Y multivalue conversion.

Note that in Fig. 18, "_" means non-execution of dot printing with C or M ink; "c", dot printing with small-sized C ink droplet (or thin C ink); "m", dot printing with small-sized M ink droplet (or thin M ink); "C", dot printing with large-sized C ink droplet (or thick C ink); "M", dot printing with large-sized M ink droplet (or thick M ink); "cm", dot printing with small-sized C ink droplet (or thin C ink) and small-sized M ink droplet (or thin M ink); "Cm", dot printing with large-sized C ink droplet (or thick C ink) and small-sized M ink droplet (or thin M ink); "cM", dot printing with small-sized C ink droplet (or thin C ink) and large-sized M ink droplet (or thick M ink); and "CM", dot printing with large-sized C ink droplet (or thick C ink) and large-sized M ink droplet (or thick M ink).

Actually, it is desirable that two-dimensional tables are prepared respectively for the C and M components in consideration of color characteristics of the C and M components, as shown in Figs. 19A and 19B.

Fig. 19A shows a two-dimensional table specialized for the C component, and Fig. 19B, a two-dimensional table specialized for the M component.

Further, in Figs. 19A and B, "_" means non-execution of dot printing; "c", dot printing with small-sized C ink droplet (or thin C ink); "m", dot printing with small-sized M ink droplet (or thin M ink); "C", dot printing with large-sized C ink droplet (or thick C ink); and "M", dot printing with large-sized M ink droplet (or thick M ink).

In the above example, for the sake of simplification of explanation, ternarization has been described, however, in the present embodiment, as conversion into N-ary code ($N \geq 4$) can be realized by using simple processing steps without conditional branch processing, i.e., XY calculation, XY multivalue conversion processing and multivalue conversion of the C and M components, the embodiment provides more effective processing for N of the higher-order.

Accordingly, in the above-described present embodiment, regarding conversion into N-ary code of the higher-order, the error diffusion processing can be performed at a high speed without complicated processing.

Further, according to the above-described present embodiment, as the processing is mainly performed with reference to table(s) without calculation accompanied with condition determination, the processing is advantageous in e.g. pipeline processing and/or lookahead processing used in an MPU such as an Pentium compatible processor. If such processor is employed in the present embodiment, higher-speed processing can be expected.

[Sixth Embodiment]

In the present embodiment, the error diffusion processing capable of controlling pixel arrangement by each density component in accordance with density value, different from the error diffusion of the conventional art, will be described. The error diffusion processing according to the present embodiment handles multivalued image data of C and M components.

In the present embodiment, the multivalued density data is binarized by the error-diffusion processing.

Fig. 20 is a flowchart showing the image formation control according to the sixth embodiment of the present invention.

Hereinbelow, the feature of the present embodiment will be described with reference to the flowchart.

First, at step S610, the density values Ct and Mt of the C and M components of pixel of interest are

obtained as in the case of the conventional art. Next, at step S620, it is determined whether or not the sum of the obtained M component density value Mt and the C component density value Ct is greater than a density value 127 used as a threshold value. If Ct+Mt>127 holds, the process proceeds to step S630, at which the M component density value Mt and the C component density value Ct are compared with each other.

If Ct>Mt holds, the process proceeds to step S640, at which setting is made for printing with the C ink. Further, at step S650, it is determined whether or not the M component density value Mt is greater than the threshold value 127. If Mt>127 holds, the process proceeds to step S670, at which setting is made for printing with the M ink. Then the process ends. On the other hand, if Mt≤127 holds, the process skips step S670 and the process ends.

At step S630, if Ct≤Mt holds, the process proceeds to step S680, at which setting is made for printing with the M ink. Further, the process proceeds to step S690, at which it is determined whether or not the C component density value Ct is greater than the threshold value 127. If Ct>127 holds, the process proceeds to step S700, at which setting is made for printing with the C ink. Then, the process ends. On the other hand, if Ct≤127 holds, the process skips step S700 and the process ends.

Further, at step S620, if $Ct+Mt \leq 127$ holds, the process ends.

Fig. 21 is a diagram showing threshold conditions for the C and M components in the processing shown in Fig. 20.

In the above-described processing, the following dot arrangements are made in accordance with the M component density value Mt and the C component density value Ct.

(1) $Ct+Mt \leq 127$

(C and M components belong to low density area → area (a) in Fig. 21)

Dot printing is not performed.

(2) $Ct+Mt>127$ and $Ct>Mt$ and $Mt>127$

(C and M components belong to intermediate to high density area → area (d) in Fig. 21)

Dot printing with C and M inks (overlay printing).

(3) $Ct+Mt>127$ and $Ct>Mt$ and $Mt \leq 127$

(only C component belongs to intermediate to high density area → area (b) in Fig. 21)

Dot printing with only C ink (exclusive printing).

(4) $Ct+Mt>127$ and $Ct \leq Mt$ and $Ct>127$

(C and M components belong to intermediate to high density area → area (d) in Fig. 21)

Dot printing with C and M inks (overlay printing).

(5) $Ct+Mt>127$ and $Ct\leq Mt$ and $Ct\leq 127$

(only M component belongs to intermediate to high density area → area (c) in Fig. 21)

Dot printing with only M ink (exclusive printing).

Accordingly, in the above-described embodiment, if only one density component has a sufficiently high density, printing pixels are formed for the color component without depending on another component. Thus, printing independency of the C and M components in intermediate to high density areas is enhanced. Thus the uniformity of image can be maintained in intermediate and higher density areas.

[Seventh Embodiment]

In the sixth embodiment, the multivalued density data is binarized by the error diffusion processing; in the present embodiment, multivalued density data is ternarized by the error diffusion processing.

Fig. 22 is a flowchart showing the image formation control according to the seventh embodiment of the present invention.

Hereinbelow, the feature of the present embodiment will be described with reference to the flowchart.

First, at step S710, the density values Ct and Mt of the C and M components of pixel of interest are obtained as in the case of the conventional art. Next, at step S720, the sum of the obtained M component density value Mt and the C component density value Ct is compared with a threshold value (Threshold). If Ct+Mt>Threshold holds, the process proceeds to step S730, while if Ct+Mt≤Threshold holds, proceeds to step S760.

At step S730, the M component density value Mt and the C component density value Ct are compared with each other. If Ct>Mt holds, the process proceeds to step S740, at which output values by the error diffusion processing of the C and M components are determined.

That is, a common multivalue conversion table for the C and M components as shown in Table 10 is used. First, as the C component output value (C out), a greater one of "1" and f(Ct) value (in multivalue conversion table as a function of a density value Ct) is selected. For example, if f(Ct) is "0", C out=1 holds; if f(Ct) is "1", C out=1 holds; and if f(Ct) is "2", C out=2 holds.

Further, as the M component output value (M out), a value corresponding to the density value Mt is determined by referring to the multivalue conversion table of Table 10, as M out=g(Mt)(in multivalue conversion table as a function of a density value Mt).

Further, if Ct≤Mt holds, the process proceeds to step S750, at which the common multivalue conversion table for the C and M components shown in the Table 10 is referred to, and the output values from the error diffusion processing of the C and M components are determined.

That is, as the C component output value (C out), a value corresponding to the density value Ct is determined by referring to the multivalue conversion table of Table 10, as C out=f(Ct), and as the M component output value (M out), a greater one of "1" and g(Mt) value (in multivalue conversion table as a function of a density value Mt) is selected.

Further, at step S760, the common multivalue conversion table for the C and M components shown in the Table 10 is referred to, then, as the C component output value (C out), a value corresponding to the density value Ct is determined by referring to the multivalue conversion table in Table 10, as C out=f(Ct), and as the M component output value (M out), a value corresponding to the density value Mt is determined by referring to the multivalue conversion table of Table 10, as M out=g(Mt).

After steps S740 and S750 or S760, the process ends.

Note that in this embodiment, "85" is used as the threshold value (Threshold).

Fig. 23 is a diagram showing threshold conditions regarding the C and M components in the processing shown in Fig. 22.

Further, in the present embodiment, for the sake of simplification of explanation, a common table is used as the multivalue conversion tables f(Ct) and g(Mt), however, the common table is not necessarily used but separate tables may be used.

Further, Table 10 merely has density values 0 to 255, however, as actual density values Ct and Mt may have density variation widths, which may differ in accordance with conditions of multivalue conversion means and error diffusion method, about -128 to +383 at the maximum, the present invention is not limited to the values shown in Table 10. In the present embodiment, although the following values are not included for the sake of simplification of explanation, actually unshown Ct(Mt) table part of "0" or less may have the same values of those in the Ct(Mt)=0 multivalue conversion table, and unshown Ct(Mt) table part of "255" or more may have the same values of those in the Ct(Mt)=255 multivalue conversion table.

Note that in the present embodiment, only ternarization is handled, however, if the ink-jet printer as the image output device is capable of handling quaternary or quinary representation by using drop modulation and same-color various density ink (e.g.

thin cyan ink, thick cyan ink, thin magenta ink and thick magenta ink), threshold tables for multivalue error diffusion processing such as quaternarization or quinarization may be generated.

Accordingly, in the above-described embodiment, even in conversion of multivalued image data into N-ary code, as the processing is performed by using a predetermined format threshold table, even if the threshold conditions are complicated, the processing can be performed in a simple manner, and as the processing is simple, the complicated threshold conditional process can be performed at a high speed.

Note that in the above embodiments, the liquid discharged from the printhead has been described as ink, and the liquid contained in the ink tank has been described as ink. However, the liquid is not limited to ink. For example, the ink tank may contain processed liquid or the like discharged to a print medium to improve fixability or water repellency of a printed image or to increase the image quality.

The embodiments described above have exemplified a printer, which comprises means (e.g., an electrothermal transducer, laser beam generator, and the like) for generating heat energy as energy utilized upon execution of ink discharge, and causes a change in state of an ink by the heat energy, among the ink-jet printers. According to this ink-jet printer and printing method, a

high-density, high-precision printing operation can be attained.

As the typical arrangement and principle of the ink-jet printing system, one practiced by use of the basic principle disclosed in, for example, U.S. Patent Nos. 4,723,129 and 4,740,796 is preferable. The above system is applicable to either one of the so-called on-demand type or a continuous type. Particularly, in the case of the on-demand type, the system is effective because, by applying at least one driving signal, which corresponds to printing information and gives a rapid temperature rise exceeding nucleate boiling, to each of electrothermal transducers arranged in correspondence with a sheet or liquid channels holding a liquid (ink), heat energy is generated by the electrothermal transducer to effect film boiling on the heat acting surface of the printhead, and consequently, a bubble can be formed in the liquid (ink) in one-to-one correspondence with the driving signal. By discharging the liquid (ink) through a discharge opening by growth and shrinkage of the bubble, at least one droplet is formed. If the driving signal is applied as a pulse signal, the growth and shrinkage of the bubble can be attained instantly and adequately to achieve discharge of the liquid (ink) with the particularly high response characteristics.

As the pulse driving signal, signals disclosed in U.S. Patent Nos. 4,463,359 and 4,345,262 are suitable. Note that further excellent printing can be performed by using the conditions described in U.S. Patent No. 4,313,124 of the invention which relates to the temperature rise rate of the heat acting surface.

As an arrangement of the printhead, in addition to the arrangement as a combination of discharge nozzles, liquid channels, and electrothermal transducers (linear liquid channels or right angle liquid channels) as disclosed in the above specifications, the arrangement using U.S. Patent Nos. 4,558,333 and 4,459,600, which disclose the arrangement having a heat acting portion arranged in a flexed region is also included in the present invention. In addition, the present invention can be effectively applied to an arrangement based on Japanese Patent Laid-Open Publication No. 59-123670 which discloses the arrangement using a slot common to a plurality of electrothermal transducers as a discharge portion of the electrothermal transducers, or Japanese Patent Laid-Open No. 59-138461 Publication which discloses the arrangement having an opening for absorbing a pressure wave of heat energy in correspondence with a discharge portion.

Furthermore, as a full line type printhead having a length corresponding to the width of a maximum printing medium which can be printed by the printer,

either the arrangement which satisfies the full-line length by combining a plurality of printheads as disclosed in the above specification or the arrangement as a single printhead obtained by forming printheads integrally can be used.

In addition, an exchangeable chip type printhead which can be electrically connected to the apparatus main body and can receive ink from the apparatus main body upon being mounted on the apparatus main body can be employed as well as a cartridge type printhead in which an ink tank is integrally arranged on the printhead itself as described in the above embodiments.

It is preferable to add recovery means for the printhead, preliminary auxiliary means and the like to the above-described construction of the printer of the present invention since the printing operation can be further stabilized. Examples of such means include, for the printhead, capping means, cleaning means, pressurization or suction means, and preliminary heating means using electrothermal transducers, another heating element, or a combination thereof. It is also effective for stable printing to provide a preliminary discharge mode which performs discharge independently of printing.

Furthermore, as a printing mode of the printer, not only a printing mode using only a primary color such as black or the like, but also at least one of a multi-color mode using a plurality of different colors or a

full-color mode achieved by color mixing can be implemented in the printer either by using an integrated printhead or by combining a plurality of printheads.

Moreover, in each of the above-mentioned embodiments of the present invention, it is assumed that the ink is a liquid. Alternatively, the present invention may employ an ink which is solid at room temperature or less and softens or liquefies at room temperature, or an ink which liquefies upon application of a use printing signal, since it is a general practice to perform temperature control of the ink itself within a range from 30°C to 70°C in the ink-jet system, so that the ink viscosity can fall within a stable discharge range.

In addition, in order to prevent a temperature rise caused by heat energy by positively utilizing it as energy for causing a change in state of the ink from a solid state to a liquid state, or to prevent evaporation of the ink, an ink which is solid in a non-use state and liquefies upon heating may be used. In any case, an ink which liquefies upon application of heat energy according to a printing signal and is discharged in a liquid state, an ink which begins to solidify when it reaches a printing medium, or the like, is applicable to the present invention. In this case, an ink may be situated opposite electrothermal transducers while being held in a liquid or solid state in recess portions of a

porous sheet or through holes, as described in Japanese Patent Laid-Open Publication No. 54-56847 or 60-71260. In the present invention, the above-mentioned film boiling method is most effective for the above-mentioned inks.

In addition, the ink-jet printer of the present invention may be used in the form of a copying machine combined with a reader and the like, or a facsimile apparatus having a transmission/reception function in addition to an image output terminal of an information processing apparatus such as a computer.

The present invention can be applied to a system constituted by a plurality of devices (e.g., a host computer, an interface, a reader and a printer) or to an apparatus comprising a single device (e.g., a copy machine or a facsimile apparatus).

Further, the object of the present invention can be also achieved by providing a storage medium (or recording medium) storing software program code for performing the aforesaid processes to a system or an apparatus, reading the program code with a computer (e.g., CPU, MPU) of the system or apparatus from the storage medium, then executing the program. In this case, the program code read from the storage medium realizes the functions according to the embodiments, and the storage medium storing the program code constitutes the invention. Furthermore, besides aforesaid functions

according to the above embodiments are realized by executing the program code which is read by a computer, the present invention includes a case where an OS (operating system) or the like working on the computer performs a part or entire processes in accordance with designations of the program code and realizes functions according to the above embodiments.

Furthermore, the present invention also includes a case where, after the program code read from the storage medium is written in a function expansion card which is inserted into the computer or in a memory provided in a function expansion unit which is connected to the computer, CPU or the like contained in the function expansion card or unit performs a part or entire process in accordance with designations of the program code and realizes functions of the above embodiments.

As many apparently widely different embodiments of the present invention can be made without departing from the spirit and scope thereof, it is to be understood that the invention is not limited to the specific embodiments thereof except as defined in the appended claims.